

# RESEARCH IN SEISMOLOGY

by  
Carl Kinsinger and Otto W. Nuttli

Department of Earth and Atmospheric Sciences  
Saint Louis University  
St. Louis, Missouri 63103

Contract No. F19628-76-C-0036  
Project No. 8652

## SEMI-ANNUAL TECHNICAL REPORT

31 July 1972

Contract Monitor: Stanley M. Needleman  
Terrestrial Sciences Laboratory

Approved for public release; distribution unlimited.

NATIONAL TECHNICAL  
INFORMATION SERVICE

Sponsored by  
Defense Advanced Research Projects Agency  
ARPA Order No. 0292

Air Force Cambridge Research Laboratories  
Air Force Systems Command  
United States Air Force  
Bedford, Massachusetts 01730

D D C  
RECEIVED  
OCT 16 1972  
REGISTERED

**BEST  
AVAILABLE COPY**

ARPA order no. 0022

Program code no. 0F18

Saint Louis University

Effective date of contract:  
1 September 1972

Contract no. F34620-JH-C10016

Principal Investigator and sponsor:  
Dr. Olga W. Natch (114 225 2200 - Ext. 1222)

AFCHL order, contract and phone no.  
Stanley M. Marshall (617 847 2200)

Contract expiration date 30 December 1972

SEARCHED BY	
DATE	Index Section <input checked="" type="checkbox"/>
W C	Ref. Section <input type="checkbox"/>
UNCLASSIFIED	<input type="checkbox"/>
JUSTICE CATEGORY	
BY	
DISSEMINATION/AVAILABILITY CODE	
A	

Qualified requestors may obtain additional copies from the Defense Documentation Center. All others should apply to the National Technical Information Service.

Unclassified

Security Classification

## DOCUMENT CONTROL DATA - R &amp; D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Saint Louis University Department of Earth and Atmospheric Sciences St. Louis, Missouri 63103		2a. REPORT SECURITY CLASSIFICATION Unclassified	
2b. GROUP			
3. REPORT TITLE RESEARCH IN SEISMOLOGY			
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Scientific. Interim.			
5. AUTHOR(S) (First name, middle initial, last name) Carl Kisslinger Otto W. Nuttli			
6. REPORT DATE 31 July 1972		7a. TOTAL NO. OF PAGES 8	7b. NO. OF REFS 7
8a. CONTRACT OR GRANT NO. ARPA Order No. 0292 F19628-70-C-0036		9a. ORIGINATOR'S REPORT NUMBER(S) Semi-Annual Technical Report	
8b. PROJECT NO., Task, Work Unit Nos. 8652 n/a n/a c. DoD Element 62701D d. DoD Subelement n/a		9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) AFCRL-72-0405	
10. DISTRIBUTION STATEMENT A - Approved for public release; distribution unlimited.			
11. SUPPLEMENTARY NOTES This research was supported by the Defense Advanced Research Projects Agency.		12. SPONSORING MILITARY ACTIVITY Air Force Cambridge Research Laboratories (LW) L. G. Hanscom Field Bedford, Massachusetts 01730	
13. ABSTRACT This report concerns research related to the discrimination between small-magnitude earthquakes and explosions. The principal findings are: The source spectra of small-magnitude earthquakes in the New Madrid (Lower Mississippi Valley) seismic region can be divided into two classes, one of which is deficient in low-frequency energy. In most cases the source spectrum of P waves from deep-focus South American earthquakes is flat at the low frequencies and falls off as the inverse square of the frequency at the high frequencies. The absorption of surface waves is much smaller east of the Rocky Mountains than west of them. This fact must be taken into account when computing surface-wave magnitudes of small events.			

1 A

**Security Classification**

14.

### KEY WORDS

LINK A

NAME	ROLE
1. [Name]	[Role]
2. [Name]	[Role]
3. [Name]	[Role]
4. [Name]	[Role]
5. [Name]	[Role]
6. [Name]	[Role]
7. [Name]	[Role]
8. [Name]	[Role]
9. [Name]	[Role]
10. [Name]	[Role]
11. [Name]	[Role]
12. [Name]	[Role]
13. [Name]	[Role]
14. [Name]	[Role]
15. [Name]	[Role]
16. [Name]	[Role]
17. [Name]	[Role]
18. [Name]	[Role]
19. [Name]	[Role]
20. [Name]	[Role]
21. [Name]	[Role]
22. [Name]	[Role]
23. [Name]	[Role]
24. [Name]	[Role]
25. [Name]	[Role]
26. [Name]	[Role]
27. [Name]	[Role]
28. [Name]	[Role]
29. [Name]	[Role]
30. [Name]	[Role]
31. [Name]	[Role]
32. [Name]	[Role]
33. [Name]	[Role]
34. [Name]	[Role]
35. [Name]	[Role]
36. [Name]	[Role]
37. [Name]	[Role]
38. [Name]	[Role]
39. [Name]	[Role]
40. [Name]	[Role]
41. [Name]	[Role]
42. [Name]	[Role]
43. [Name]	[Role]
44. [Name]	[Role]
45. [Name]	[Role]
46. [Name]	[Role]
47. [Name]	[Role]
48. [Name]	[Role]
49. [Name]	[Role]
50. [Name]	[Role]
51. [Name]	[Role]
52. [Name]	[Role]
53. [Name]	[Role]
54. [Name]	[Role]
55. [Name]	[Role]
56. [Name]	[Role]
57. [Name]	[Role]
58. [Name]	[Role]
59. [Name]	[Role]
60. [Name]	[Role]
61. [Name]	[Role]
62. [Name]	[Role]
63. [Name]	[Role]
64. [Name]	[Role]
65. [Name]	[Role]
66. [Name]	[Role]
67. [Name]	[Role]
68. [Name]	[Role]
69. [Name]	[Role]
70. [Name]	[Role]
71. [Name]	[Role]
72. [Name]	[Role]
73. [Name]	[Role]
74. [Name]	[Role]
75. [Name]	[Role]
76. [Name]	[Role]
77. [Name]	[Role]
78. [Name]	[Role]
79. [Name]	[Role]
80. [Name]	[Role]
81. [Name]	[Role]
82. [Name]	[Role]
83. [Name]	[Role]
84. [Name]	[Role]
85. [Name]	[Role]
86. [Name]	[Role]
87. [Name]	[Role]
88. [Name]	[Role]
89. [Name]	[Role]
90. [Name]	[Role]
91. [Name]	[Role]
92. [Name]	[Role]
93. [Name]	[Role]
94. [Name]	[Role]
95. [Name]	[Role]
96. [Name]	[Role]
97. [Name]	[Role]
98. [Name]	[Role]
99. [Name]	[Role]
100. [Name]	[Role]

WT

LINK B

### ROLE

WT

**LINK C**

ROLE

WT

Source spectrum  
Earthquake magnitudes  
Seismic body waves  
Seismic surface waves

15

Unclassified  
Security Classification

# **RESEARCH IN SEISMOLOGY**

by  
**Carl Kisslinger and Otto W. Nuttli**

**Department of Earth and Atmospheric Sciences  
- Saint Louis University  
St. Louis, Missouri 63103**

**Contract No. F19628-70-C-0036  
Project No. 8652**

## **SEMI-ANNUAL TECHNICAL REPORT**

**31 July 1972**

**Contract Monitor: Stanley M. Needleman  
Terrestrial Sciences Laboratory**

**Approved for public release; distribution unlimited.**

**Sponsored by  
Defense Advanced Research Projects Agency  
ARPA Order No. 0292**

**Air Force Cambridge Research Laboratories  
Air Force Systems Command  
United States Air Force  
Bedford, Massachusetts 01730**

## Introduction

During the six months covered by this report attention has been centered on problems related to discrimination of small-magnitude events. This includes studies on the shape of the source spectrum for shallow and deep events, on the attenuation of short-period surface waves, and of magnitude formulas for  $m_b$  and  $M_s$  that can be used for small events.

Eight earthquakes with  $m_b$  values between 2 and 4 were detected, and their hypocentral coordinates determined, during the interval 1 January to 30 June, 1972. All these earthquakes were located in the New Madrid Seismic Zone. They provide additional data for our studies of the spectral properties and magnitude relations of small, shallow-depth events.

### Spectral Analysis Studies of Events in the New Madrid Seismic Zone.

A study of the spectral content of 17 earthquakes established that the earthquakes divide into two classes, one of which is deficient in low-frequency (long period) energy. The spectra were determined by both digital and analog methods, to rule out the possibility of errors in the calculation of the spectra. The two classes of earthquakes also differ in their macroseismic effects. The events deficient in the long-period motion are characterized by relatively higher intensity at the epicenter, but a smaller area of perceptibility.

The spectral differences are seen for both the P and S (or Lg) waves. As the cause of the differences is not yet certain, study is continuing to determine the explanation. The spectral differences appear not to be related to depth of focus or location within the seismic zone, but rather to something different in the faulting process.

The existence of small, shallow-depth earthquakes with spectra rich in high frequencies (or relatively poor in low frequencies) is important to the VELA-Uniform problem in terms of application of discrimination criteria.

### Spectral Analysis Studies of Deep-Focus South American Earthquakes.

Studies to determine the source spectrum of deep-focus South American earthquakes from seismograms obtained at South American stations were begun in the summer of 1971. During the six-month period covered by this report the data of more earthquakes were analyzed.

From the additional analyses we now can conclude that in most cases the source spectrum for the P waves falls off as  $f^{-2}$  for the high frequencies and is flat at the low frequencies. There is one exception to this statement; the spectrum of the 5 March 1965 earthquake calculated from the ANT seismograms is peaked at intermediate frequencies. The shape of these spectra is in general consistent with that predicted by the theories of Brune and of Ferckhemer and Jacob. Although both theories give seismic moments of the same order of magnitude, Brune's theory gives consistently longer fault lengths and lower stress drops.

#### Attenuation and Magnitude Relations.

Studies of the attenuation of seismic surface waves have established that the empirical  $M_L$  scale of Richter and  $M_S$  scale of Gutenberg and Richter can be given a theoretical foundation. These studies further established that magnitude formulas of the type

$$M = B + C \log A + \log A/T,$$

which are in common use, only are valid over a limited range of epicentral distances. Application of such formulas to data outside the range of validity will lead to incorrect magnitude determinations.

The attenuation studies also established that the absorption of short-period surface waves is much smaller east of the Rocky Mountains than west of them. Thus magnitude formulas which use data at regional distances (about 200 to 2000 km) that are obtained empirically from California and NTS events are not valid for Central United States earthquakes. In general they result in overestimation of the surface-wave magnitude.

Of interest to VELA-Uniform objectives is the likelihood that geologic structure, and thus surface-wave attenuation, of central Asia is likely more similar to that in the Central United States than to California and Nevada.



Reports and Scientific Papers Produced during  
the Report Period.

1. AFCRL-72-0158, Scientific Report No. 6.  
Syed, A. A. and O. W. Nuttli, "A Method of Correcting P-Wave Magnitudes for the Effect of Earthquake Focal Mechanism," Reprinted from Bulletin of the Seismological Society of America, 61: 1811-1826, 1971.
2. AFCRL-72-0159, Scientific Report No. 7.  
Syed, A. A., C. Kisslinger and O. W. Nuttli, "A Seismic Discriminant Based on Focal Mechanism," Reprinted from the Bulletin of the Seismological Society of America, 61: 1827-1830, 1971.
3. AFCRL-72-0316, Scientific Report No. 8  
Rogers, A. M., Jr. and C. Kisslinger, "The Effect of a Dipping Layer on P-Wave Transmission," Reprinted from the Bulletin of the Seismological Society of America, 62: 301-324, 1972.
4. AFCRL-72-0317, Scientific Report No. 9  
Nuttli, O. W., "The Amplitudes of Teleseismic P Waves," Reprinted from the Bulletin of the Seismological Society of America, 62: 343-356, 1972.
5. AFCRL-72-0331, Scientific Report No. 10.  
Stauder, W. "Fault Motion and Spatially Bounded Character of Earthquakes in Amchitka Pass and the Delarof Islands," Reprinted from the Journal of Geophysical Research, 77: 2072-2080, 1972.
6. Rodriguez, R. and C. Kisslinger, "Spectral Classification of New Madrid Earthquakes," presented to 1972 Spring Meeting of the American Geophysical Union.
7. Nuttli, O. W. "Seismic Wave Attenuation and Magnitude Relations for Eastern North America," presented to 1972 Spring Meeting of the American Geophysical Union. (A manuscript of the same title has been submitted to the Journal of Geophysical Research.)